

WHAT IS CLAIMED IS:

1. A method for incrementally reducing, and subsequently eliminating by sequestration, the emissions of carbon dioxide from the combustion of solid fossil fuels, in energy systems that contain components including one or more of furnaces, boilers, and heat engines, comprising:

changing the processes by which said fuels are gasified and burned so as to produce hydrogen; and

eliminating one or more other gaseous species selected from the group consisting of nitrogen oxides, sulfur oxides, volatile trace metals, mercury, and dioxins and furans that are emitted during the operation of said energy systems.

2. The method of claim 1, further comprising:

operating a primary combustor or boiler under fuel rich conditions to reduce NO<sub>x</sub> emissions by combustion at a stoichiometric ratio in the range of 0.60 to 0.8, causing or allowing up to nominally 20% of the carbon in the solid fossil fuel to remain unburned;

collecting the unburned carbon with fly ash upstream of a stack for storage either at the original combustion site for future combustion of the unburned carbon and sequestration of the carbon dioxide or for shipping to a site suitable for underground sequestration after the combustion, thereby reducing carbon dioxide emissions to the atmosphere; and

combusting the unburned carbon in systems equipped with carbon dioxide sequestration methods.

3. The method of claim 2, further comprising selling unneeded NO<sub>x</sub> emission rights that result from operating at fuel rich conditions.

5 4. The method of claim 1, wherein the solid fossil fuel is coal and the carbon dioxide sequestration is preceded by a series of steps comprising:

pyrolyzing said coal at a nominal temperature sufficient to evolve gaseous volatile matter at about 1500°F in a pyrolyzing vessel that is pressurized with steam that is bled from a power plant's steam turbine at a nominal pressure of about  
10 150 psi;

heating said coal in said pyrolyzing vessel directly using said steam and indirectly using carbon dioxide and nitrogen that evolve from calcination of calcium carbonate and flow through pipes that are embedded in said pyrolyzing vessel;

15 mixing said gaseous volatile matter in a hydrogen production vessel with additional steam bled from said turbine and, optionally, further heating said gaseous volatile matter and said additional steam with effluent of an oxygen fired natural gas combustor;

mixing said gaseous volatile matter in said hydrogen production vessel with calcium oxide particles drawn from a calciner vessel at a temperature that converts the mixture to hydrogen gas, leaving calcium carbonate particles;

cleaning said hydrogen gas in a sand filled vessel or other hot gas cleanup device, followed by one of firing said hydrogen gas with air in a combined gas-steam turbine power plant and processing said hydrogen gas for sale as a transportation fuel or chemical feedstock;

pneumatically recirculating said calcium carbonate particles to said calciner vessel, such that energy for recalcination is supplied from a slagging combustor that is fired directly with a fraction of residual char removed from said pyrolyzing vessel and with air that is preheated with the above atmospheric pressure nitrogen and carbon dioxide effluent from said calciner vessel flowing through a falling solid particle bed regenerative heat exchanger;

firing the residual char removed from said pyrolyzer vessel in one or more slagging combustors that are attached to either one or more new boilers or retrofitted to one or more existing coal fired boilers that are modified with said slagging combustors, said residual char having an energy content about equal to an energy content of the coal that would have been fired in an unmodified boiler;

processing combustion products from said char heated boiler within a combustion zone in each slagging combustor of the slagging combustors and in a post-combustion zone of said boiler to which said slagging combustors are attached thereto to remove one or more pollutants selected from the group consisting of

nitrogen oxides, sulfur dioxides, hydrogen chlorides, dioxins, furans and volatile trace metal that are not retained in slag removed from said slagging combustor,

leaving carbon dioxide and nitrogen in an exhaust duct upstream of ash particle collectors,

5 mixing the carbon dioxide and nitrogen in said exhaust duct with the carbon dioxide and nitrogen that are removed from said hydrogen production vessel,

spraying water droplets into the exhausted duct containing the mixed carbon dioxide and nitrogen to cool them to ambient temperature,

compressing said carbon dioxide and nitrogen, being at near the ambient temperature, with pressurized water such that the carbon dioxide remains in solution at a pressure suitable for sequestration with calcium carbonate formations,

10 expanding the nitrogen of the mixed carbon dioxide and nitrogen solution through a turbine to recover compression energy,

wherein, optionally, the hydrogen withdrawn from said hydrogen production vessel is used for on site power generation, as a transportation fuel, or as a chemical feedstock.

5. The method of claim 4, further comprising using renewable agricultural residue or forest product waste to produce hydrogen in systems of about 1 to 20 megawatt electric power output, said systems being quasi-portable to allow their relocation to different regions during crop or tree harvest periods, wherein hydrogen produced by said agricultural residue or forest product waste is sold as a

transportation fuel or as chemical feedstock, and residual char is shipped to regional power plants.

6. The method of claim 2, further comprising:

collecting unburned carbon from products of the combustion for later

5 combustion;

combusting the unburned carbon; and

sequestering carbon dioxide produced by the combusting.

7. The method of claim 6, further comprising:

processing the combustion products from a char heated boiler within a

10 combustion zone in slagging combustors and in a post-combustion zone of a boiler to

which said slagging combustors are attached thereto to remove one or more pollutants

selected from the group consisting of nitrogen oxides, sulfur dioxides, hydrogen

chlorides, dioxins, furans and volatile trace metal that are not retained in slag

removed from said slagging combustors;

15 further cooling said carbon dioxide and nitrogen gas mixture to

ambient conditions by spraying water droplets into an exhaust duct of said boiler

upstream of a particle collection equipment, and

compressing carbon dioxide and nitrogen effluent stream from a

mixing thereof to a pressure suitable for subterranean sequestration;

mixing the compressed carbon dioxide and nitrogen effluent stream from said compressing step with an amount of water to form an aqueous solution containing dissolved carbon dioxide;

separating the nitrogen gas from the carbon dioxide and nitrogen effluent stream of said compressing step from the aqueous solution containing dissolved carbon dioxide and expanding the nitrogen gas through a turbine to recover at least a portion of energy used in said compressing step; and

sequestering the solution containing carbon dioxide by placing it at a subterranean depth.

10           8.       The method of claim 7 wherein the solid fuel is coal.

9.       The method of claim 7, wherein the aqueous solution containing carbon dioxide reacts with subterranean limestone during the sequestering step.

10.      The method of claim 4, wherein, in power plants located in region having inadequate water supplies for forming dissolved carbon dioxide solutions, said sequestering step comprises:

injecting heated calcium oxide particles into char fired boiler gases whose temperature is about 700°C to react with the carbon dioxide to form calcium carbonate;

calcining said calcium carbonate in a separate calcining vessel that is fired with char in at least one of the slagging combustors to evolve gaseous carbon dioxide;

compressing cooled gaseous carbon dioxide; and

5 injecting the compressed carbon dioxide into a geologic formation, a spent gas well, or a saline formation.

11. The method of claim 7, wherein, in power plants in regions having inadequate water supplies for forming dissolved carbon dioxide solutions said sequestering step comprises:

10 injecting heated calcium oxide particles into said char fired boiler gases whose temperature is about 700°C to react with the carbon dioxide to form calcium carbonate;

calcining the calcium carbonate in a separate calcining vessel that is fired with char in a slagging combustor to evolve gaseous carbon dioxide;

15 compressing the gaseous carbon dioxide; and

injecting the compressed carbon dioxide into a geologic formation, a spent gas well, or a saline formation.

12. The method of claim 4, wherein said sequestering step further comprises:

causing or allowing the carbon dioxide to mix with underground water  
to form carbonic acid ; and

causing or allowing the carbonic acid to mix with underground  
limestone to form calcium hydrogen carbonate.

5           13.    The method of claim 7, wherein said sequestering step further  
comprises:

causing or allowing the carbon dioxide to mix with underground water  
to form carbonic acid; and

                  causing or allowing the carbonic acid to mix with underground  
10   limestone to form calcium hydrogen carbonate.

14.    The method of claim 10, wherein pollutants including at least sulfur  
dioxide and nitrogen oxide are removed upstream of carbon dioxide removal by  
reaction with getters, with said removal occurring at gas temperatures above 1700° F.

15       15.    The method of claim 11, wherein pollutants including at least sulfur  
dioxide and nitrogen oxide are removed upstream of said carbon dioxide removal step  
by reaction with getters, with said removal occurring at gas temperatures above 1700°  
F.

16.    A method for increasing the electric power output of an existing coal  
fired power plant by replacing existing pulverized coal fuel with crushed or



pulverized char fuel using either existing burners or retrofitting a boiler of the existing coal fired power plant with air-cooled slagging combustors.

17. The method in accordance with claim 16, wherein the volatile matter in the coal fuel is pyrolyzed in one or more pyrolyzing vessels fired with char and compressed air at nominally 150 psig air using one or more, pressurized air-cooled slagging combustors, or heated indirectly through high alloy metal pipes inserted in the pyrolyzing vessels using combustion gases drawn from an existing char fired boiler and directly heated and pressurized with nominally 150 psi steam drawn from a steam turbine of the existing power plant.

18. The method in accordance with claim 17, wherein pyrolysis gas is cleaned in a filter and then utilized to fire a combined gas turbine-steam turbine power plant.

19. A method in accordance with claim 16, wherein the combustion products from said char heated boiler are processed within a combustion zone in each slagging combustor of slagging combustors and in a post-combustion zone of said boiler to which said combustors are attached thereto to remove one or more pollutants selected from the group consisting of nitrogen oxides, sulfur dioxides, hydrogen chlorides, dioxins, furans and volatile trace metal that are not retained in slag removed from said slagging combustors.

20. A method in accordance with claim 16, wherein the existing power plant can be converted in the future to hydrogen production with addition of carbon dioxide separation and sequestration as recited in claim 4.